

Name: \_\_\_\_\_

Chemistry 3600 Fall, 2003  
First Examination  
October 3, 2003

Read over all the questions before you start to answer, as some are more difficult than others. Each question shows the number of points that it is worth in parenthesis. Show the formulas you used and all your work to get full credit. Express all answers with the correct number of sigfigs!

**Formulas:**

$$\bar{x} = \frac{\sum x_i}{n} \quad s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} \quad \mu = \bar{x} \pm \frac{ts}{\sqrt{n}} \quad F = \frac{s_1^2}{s_2^2} \quad Q = \frac{\text{gap}}{\text{range}}$$

For  $F_{\text{calc}} > F_{\text{table}}$   $t_{\text{calculated}} = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{s_1^2/n_1 + s_2^2/n_2}}$   $df = \left\{ \frac{(s_1^2/n_1 + s_2^2/n_2)^2}{\frac{(s_1^2/n_1)^2}{n_1+1} + \frac{(s_2^2/n_2)^2}{n_2+1}} \right\} - 2$

For  $F_{\text{calc}} < F_{\text{table}}$   $t_{\text{calculated}} = \frac{|\bar{x}_1 - \bar{x}_2|}{s_{\text{pooled}}} \sqrt{\frac{n_1 n_2}{n_1 + n_2}}$   $s_{\text{pooled}} = \sqrt{\frac{s_1^2(n_1-1) + s_2^2(n_2-1)}{n_1 + n_2 - 2}}$

**Tables:**

*Q* table @ 90% confidence:

<i>Q</i>	0.94	0.74	0.64	0.56	0.51	0.47	0.44	0.41
<i>N</i>	3	4	5	6	7	8	9	10

*t* table @ 95% confidence:

<i>t</i>	12.71	4.30	3.18	2.78	2.57	2.45	2.36	2.31	2.26
<i>d.f.</i>	1	2	3	4	5	6	7	8	9

*F* table @ 95% confidence:

<i>d.f.</i> ( <i>s</i> <sub>2</sub> )	<i>d.f.</i> ( <i>s</i> <sub>1</sub> )				
	2	3	4	5	6
2	19.00	19.16	19.25	19.30	19.33
3	9.55	9.28	9.12	9.01	8.94
4	6.94	6.59	6.39	6.26	6.16
5	5.79	5.41	5.19	5.05	4.95
6	5.14	4.76	4.53	4.39	4.28

1) List the steps involved in a chemical analysis (10)

**Formulate the Question/Research**

**Design a Procedure/Research**

**Sampling**

**Sample Preparation**

**Analytical Method/Analysis**

**Data Analysis/Interpretation**

**Conclusions/Final Report**

2) A 56.0 wt % solution of perchloric acid (HClO<sub>4</sub>, MW=100.458 g/mol) has a density of 1.35 g/mL. (10 total)

a) What is the formal concentration of HClO<sub>4</sub>? (5)

$$\frac{0.56 \text{ g HClO}_4}{1 \text{ g solution}} \times 1.35 \text{ g solution/mL} \times \frac{1 \text{ mol}}{100.458 \text{ g}} \times \frac{1000 \text{ mL}}{\text{L}} = 7.53 \text{ F}$$

b) Which is more accurate to state concentration in for this case, formality or molarity? Why? (5)

**HClO<sub>4</sub> is a strong acid, completely dissociated in solution. Since there is no HClO<sub>4</sub> in solution to speak of, formal concentration is more accurate than molar concentration.**

3) Repeated measurements of the zirconium concentration (Zr, 91.224 g/mol) from a soil sample gave values of 185.7, 177.4, 167.6, 181.45, and 189.3 ppm. (30 total)

a) What are the mean concentration, standard deviation, and 95% confidence interval of the Zr concentration? (10)

$$\bar{x} = \frac{\text{sum}}{n} = \frac{185.7 + 177.4 + 167.6 + 181.45 + 189.3}{5} = 180.3$$

$$s = \sqrt{\frac{\sum (x - \bar{x}_i)^2}{n - 1}} = \sqrt{\frac{(180.3 - 185.7)^2 + (180.3 - 177.4)^2 + (180.3 - 167.6)^2 + (180.3 - 181.45)^2 + (180.3 - 189.3)^2}{4}} = 8.4$$

$$\mu = \bar{x} \pm \frac{ts}{\sqrt{n}} = 180.3 \pm \frac{(2.78)(8.4)}{\sqrt{5}} = 180.3 \pm 10.4$$

b) Use the Q-test to determine if the lowest measurement can be dropped from the set with 90% confidence.

$$(10) \quad Q_{\text{calc}} = \frac{\text{Gap}}{\text{Range}} = \frac{177.4 - 167.6}{189.3 - 167.6} = 0.45$$

$$Q_{\text{table}} = 0.64 > Q_{\text{calc}}$$

**Therefore, the measurement cannot be dropped.**

c) A second soil sample analyzed 6 replicate times for Zr content gave mean=0.0195 % and standard deviation=0.00208 %. At the 95% confidence level, does this soil sample differ in Zr concentration from the soil sample in part (a)? (10)

**0.0195%, 0.00208% = 195 ppm, 20.8 ppm → → → x<sub>1</sub>=195, s<sub>1</sub>=20.8, n<sub>1</sub>=6; x<sub>2</sub>=180.3, s<sub>2</sub>=8.4, n<sub>2</sub>=5**

$$F_{\text{calc}} = \frac{s_1^2}{s_2^2} = \frac{20.8^2}{8.4^2} = 6.13$$

$$t_{\text{calc}} = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{s_1^2/n_1 + s_2^2/n_2}} = \frac{|195 - 180.3|}{\sqrt{(20.8^2/6) + (8.4^2/5)}} = 1.58$$

$$F_{\text{table}} = 6.26 > F_{\text{calc}}$$

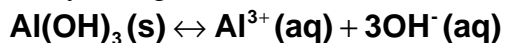
$$\text{d.f} = 7.6 \text{ (from equation)} \quad t_{\text{table}} = 2.26 > F_{\text{calc}}$$

**Therefore, there is no significant difference in the samples**

*Note: I screwed up some of the numbers here because I wanted to have you get F<sub>calc</sub> > F<sub>table</sub> to use the 2nd set of t-equations. But, the bottom line is you needed to do an F-test and then a t-test to get full credit on the problem.*

4) Aluminum hydroxide,  $\text{Al}(\text{OH})_3 (s)$  (MW=78.003) has a  $K_{sp}$  of  $5.81 \times 10^{-33}$ . (30 total)

a) How many nanograms of  $\text{Al}(\text{OH})_3$  will dissolve in 1.00 L of pure water? (10)



$$K_{sp} = 5.81 \times 10^{-33} = [\text{Al}^{3+}][\text{OH}^-]^3 \quad x = [\text{Al}^{3+}]$$

$$27x^4 = 5.81 \times 10^{-33} \Rightarrow x = 3.83 \times 10^{-9} \text{ M} = \frac{\text{mol}}{\text{L}} \times \frac{78.003 \text{ g}}{\text{mol}} = 2.99 \times 10^{-7} \text{ g} = 299 \text{ ng}$$

b) Aluminum can also form a series of complex ions in solution with hydroxide:  $\text{Al}(\text{OH})_2^+ (aq)$ ,  $\beta_1 = 1.0 \times 10^9$ ;  $\text{Al}(\text{OH})_2^+ (aq)$ ,  $\beta_2 = 5.0 \times 10^{18}$ ;  $\text{Al}(\text{OH})_3 (aq)$ ,  $\beta_3 = 1.0 \times 10^{27}$ ;  $\text{Al}(\text{OH})_4^-$ ,  $\beta_4 = 1.1 \times 10^{33}$ . Calculate the concentration of  $\text{Al}^{3+} (aq)$  and all four complex ions in a solution containing  $\text{Al}(\text{OH})_3 (s)$  where the pH is held constant at 7.8. (20)

$$\text{pOH} = 14 - 7.8 = 6.2 \rightarrow \rightarrow \rightarrow [\text{OH}^-] = -\log \text{pOH} = 10^{-6.2} = 6.31 \times 10^{-7} \text{ M}$$

$$[\text{Al}^{3+}] = K_{sp} / [\text{OH}^-]^3 = (5.81 \times 10^{-33}) / (6.31 \times 10^{-7})^3 = 2.31 \times 10^{-14} \text{ M}$$

$$[\text{Al}(\text{OH})_2^+] = \beta_1 [\text{Al}^{3+}][\text{OH}^-] = (1 \times 10^9)(2.31 \times 10^{-14})(6.31 \times 10^{-7}) = 1.5 \times 10^{-11} \text{ M}$$

$$[\text{Al}(\text{OH})_2^+] = \beta_2 [\text{Al}^{3+}][\text{OH}^-]^2 = (5.0 \times 10^{18})(2.31 \times 10^{-14})(6.31 \times 10^{-7})^2 = 4.6 \times 10^{-8} \text{ M}$$

$$[\text{Al}(\text{OH})_3] = \beta_3 [\text{Al}^{3+}][\text{OH}^-]^3 = (1.0 \times 10^{27})(2.31 \times 10^{-14})(6.31 \times 10^{-7})^3 = 5.8 \times 10^{-6} \text{ M}$$

$$[\text{Al}(\text{OH})_4^-] = \beta_4 [\text{Al}^{3+}][\text{OH}^-]^4 = (1.1 \times 10^{33})(2.31 \times 10^{-14})(6.31 \times 10^{-7})^4 = 4.0 \times 10^{-6} \text{ M}$$

5) Identify each of the following chemical species as a strong acid, strong base, weak acid, weak base, or none of the above. (10 total)

a) Ammonium ( $\text{NH}_4^+$ )

**Weak acid**

b) Bromide ion ( $\text{Br}^-$ )

**none**

c) Hydrogen iodide (HI)

**Strong acid**

d) Oxalate ion ( $\text{C}_2\text{O}_4^{2-}$ )

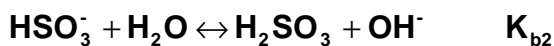
**Weak base**

e) Tetraethylammonium hydroxide ( $(\text{CH}_3\text{CH}_2)_4\text{N}^+\text{OH}^-$ )

**strong base**

6) Diprotic sulfurous acid ( $\text{H}_2\text{SO}_3$ ) is a weak acid unlike its cousin sulfuric acid.  $\text{H}_2\text{SO}_3$  has a  $K_{a1}=1.3 \times 10^{-2}$  and a  $K_{a2}=5.1 \times 10^{-6}$ . (10 total)

a) Write the association reactions for the *conjugate base* forms of sulfurous acid in water (5)



b) Determine the  $K_{b1}$  and  $K_{b2}$  equilibrium constants for the reactions in part (a) (5)

$$K_{b1} = \frac{K_w}{K_{a2}} = \frac{1 \times 10^{-14}}{5.1 \times 10^{-6}} = 2.0 \times 10^{-9}$$

$$K_{b2} = \frac{K_w}{K_{a1}} = \frac{1 \times 10^{-14}}{1.3 \times 10^{-2}} = 7.7 \times 10^{-13}$$